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Cardiac Rehabilitation After Myocardial Infarction in the Community

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OBJECTIVES The aim of this study was to examine participation in cardiac rehabilitation after myocardial infarction (MI) by age and gender and the association of participation with survival.

BACKGROUND Lesser participation in cardiac rehabilitation has been reported for women and the elderly.

METHODS All incident MIs in Olmsted County were validated. Baseline characteristics and outcomes were ascertained from the medical record. Logistic regression examined the association between participation, age, and gender. Propensity scores were used to examine the association between participation and outcome.

RESULTS Among 1,821 persons with incident MI (58% men, 46% age >70 years), 55% participated in cardiac rehabilitation. Participants were more likely to be men, younger, and have fewer comorbidities ($p < 0.01$ for all comparisons). After adjustment, women were 55% less likely to participate than men (odds ratio [OR] 0.45, 95% confidence interval [CI] 0.34 to 0.60), and persons 70 years or older were 77% less likely to participate than persons younger than 60 (OR 0.23, 95% CI 0.16 to 0.33). Participants had a lower risk of death and recurrent MI at three years ($p < 0.001$ and $p = 0.049$, respectively). The survival benefit associated with participation was stronger in more recent years (relative risk [RR] for 1998 vs. 1982 0.28, 95% CI 0.18 to 0.43; RR for 1990 vs. 1982 0.41, 95% CI 0.33 to 0.52).

CONCLUSIONS Approximately half of the patients participated in cardiac rehabilitation after MI. Participation did not increase over time. Women and elderly persons were less likely to participate, independently of other characteristics. Participation in rehabilitation was independently associated with decreased mortality and recurrent MI, and its protective effect was stronger in more recent years. (J Am Coll Cardiol 2004;44:988–96) © 2004 by the American College of Cardiology Foundation

As fatalities after acute myocardial infarction (AMI) are decreasing (1,2), the population of myocardial infarction (MI) survivors, candidates for secondary prevention, is growing. Moreover, this population is increasingly more composed of women and elderly persons (3) toward whom secondary prevention efforts thus increasingly pertain.

American College of Cardiology guidelines underscore the importance of cardiac rehabilitation as a vehicle to achieve necessary lifestyle modifications after AMI (4,5). Furthermore, as hospital stays for AMI have dramatically decreased over time, thereby reducing the opportunity for in-hospital risk factor interventions, outpatient cardiac rehabilitation programs have gradually broadened their scope to become an important avenue for secondary prevention (6).

Contrasting the reduction in hospital stay after MI and the displacement of the burden of coronary disease toward women and the elderly, participation in cardiac rehabilitation has previously been low (4,7), particularly among women and older individuals (8–10). Should these patterns of care persist, they would uncover secondary prevention gaps and opportunities for improvement in care. Furthermore, although earlier studies reported beneficial impact of cardiac rehabilitation on outcomes, these data were generated by small trials that predate the reperfusion era and included primarily middle-aged men (11,12). Thus, these findings may not be generalizable to the contemporary population or treatments in AMI.

This study was undertaken to address these gaps in knowledge and to examine participation in cardiac rehabilitation after MI in the community. It aimed to test the hypothesis that women and the elderly were less likely to participate in rehabilitation and to examine the association between participation and survival.

METHODS

Study setting. This study was conducted in Olmsted County, Minnesota. Although the diversity of the Olmsted County population is increasing, as shown by the 2000 census (13), the characteristics of the Olmsted County population during the study period were similar to those of U.S. whites. Epidemiologic studies in Olmsted County are possible because the county is relatively isolated from other urban centers and only a few providers deliver nearly all health care to local residents. Health care providers in Olmsted County include the Mayo Clinic, Olmsted Medical Center, and a handful of private practitioners. Each medical provider uses a comprehensive medical record

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Abbreviations and Acronyms

AMI	= acute myocardial infarction
CHD	= coronary heart disease
CI	= confidence interval
CK	= creatine phosphokinase
ECG	= electrocardiogram/electrocardiographic
LVEF	= left ventricular ejection fraction
MI	= myocardial infarction
OR	= odds ratio
RR	= relative risk

system in which the details of every encounter are entered and can be easily retrieved. Medical records are identified under the auspices of the Rochester Epidemiology Project, a record-linkage system that allows the indexing of all medical records of Olmsted County residents according to clinical and pathologic diagnoses, surgical procedures, and billing information. This indexing system enables the retrieval of all medical record data for use in research studies and ensures complete capture of all health care-related events occurring in Olmsted County for county residents. Death certificates are also indexed according to cause of death. This centralized system encompasses the medical records of a population representing an estimated 3,600,000 person-years of health care; its potential is described elsewhere (14,15). It is especially valuable to capture outpatient care processes (16) such as cardiac rehabilitation.

Assembling the MI incidence cohort. The methods used to assemble a cohort of patients with incident (first ever) MI followed standardized surveillance methods (17) and have been reported in detail elsewhere (3,18). Briefly, all patients dismissed from Olmsted County hospitals between 1982 and 1998 with a diagnosis compatible with MI as defined by codes from the ninth revision of the International Classification of Diseases (ICD-9) were enumerated. Target codes included 410 (AMI), 411 (other acute and subacute forms of ischemic heart disease), 412 (old MI), 413 (angina pectoris), and 414 (other forms of ischemic heart disease). All events coded as 410 and samples of other coronary heart disease (CHD) codes (411 to 414) were reviewed using sampling fractions analogous to those used in other studies (17). Trained abstractors reviewed criteria for residency in Olmsted County and ascertained incident status through complete review of the record. Information was also collected on cardiac pain, creatine phosphokinase (CK) values (transcribed for up to 3 determinations on each of the first 3 days after hospital admission), and date and time of the electrocardiograms (ECGs). The reliability of this method has been described elsewhere (3,18). Copies of up to three ECGs (first day of the event or hospital admission, third day of hospitalization, and last day of hospitalization) were printed and sent to the Electrocardiogram Reading Center at the University of Minnesota to be assigned a Minnesota Code (19). Standard epidemiologic criteria were applied to assign MI diagnosis on the basis of cardiac pain, enzyme values, and Minnesota Coding of the ECG.

Baseline characteristics, end point definitions, and ascertainment. Clinical diagnoses were used to define cardiovascular risk factors. Because of the change over time in normal values, peak CK ratio (maximum CK value divided by the upper limit of normal) was used. Comorbidity was measured by the Charlson index, a validated measure of comorbidity (20). Reperfusion therapy was defined as thrombolysis or coronary angioplasty within 24 h after admission. Ejection fraction was defined as the left ventricular ejection fraction (LVEF) measured within 30 days of the index MI.

Participation was defined as documented attendance in the medical record to the first session of structured outpatient cardiac rehabilitation programs in Olmsted County and included supervised exercise as well as counseling and education sessions. Follow-up was accrued by passive surveillance through the community inpatient and outpatient medical records. The procedures used to ascertain deaths in the study have been described elsewhere (18). Briefly, follow-up for mortality was obtained through community medical records, death certificates, and obituary notices. Deaths were classified into cardiac, cancer, and other causes, based on the underlying cause of death on the death certificates. Recurrent MI was ascertained by review of the medical record on the basis of enzyme levels and ECG changes.

Statistical analysis. The first analyses tested the hypothesis that female gender and more advanced age were associated with lesser participation in cardiac rehabilitation independently of other characteristics.

Bivariate associations between participation in cardiac rehabilitation and selected baseline characteristics were determined using chi-square tests for categorical variables and t tests for continuous variables. Results were reported as odds ratios (OR) with 95% confidence intervals (CI). With age and gender being considered as the exposures of interest, potential confounders of the relationship between gender or age and participation in cardiac rehabilitation were identified and entered into a multivariable logistic regression model to analyze the independent association between participation in cardiac rehabilitation and age or gender.

Survival and survival free of recurrent MI were analyzed using the Kaplan-Meier method. Overall survival was compared with the expected survival of the Minnesota total population.

Because of marked differences between participants and non-participants in cardiac rehabilitation, propensity scores were used to adjust for the characteristics associated with participation in cardiac rehabilitation. We fitted a logistic regression model that predicted whether a person would participate in cardiac rehabilitation as a function of 16 variables, including demographic and clinical characteristics, use of reperfusion therapy, whether a cardiologist was the

Table 1. Characteristics of 1,821 Incident MIs Eligible to Participate in Cardiac Rehabilitation

	Overall	No Cardiac Rehabilitation (n = 812)	Cardiac Rehabilitation (n = 1,000)	p Value
Age, yrs (SD)	67 (14)	74 (13)	61 (12)	<0.001
Women, n (%)	765 (42)	468 (58)	292 (29)	<0.001
Diabetes mellitus, n (%)	351 (19)	212 (26)	139 (14)	<0.001
Hypertension, n (%)	1,027 (56)	526 (65)	494 (49)	<0.001
Current smoker, n (%)	544 (30)	169 (21)	370 (37)	<0.001
Hyperlipidemia, n (%)	623 (34)	240 (30)	380 (38)	<0.001
Familial history of heart disease, n (%)	389 (23)	109 (15)	277 (29)	<0.001
Personal history of heart disease, n (%)	1,196 (66)	560 (69)	631 (63)	0.010
Charlson index, n (%)				<0.001
0	793 (44)	215 (26)	574 (57)	
1 or 2	672 (37)	332 (41)	337 (34)	
3 or more	356 (20)	265 (33)	89 (9)	
Ejection fraction, mean (SD)	50 (15)	47 (16)	53 (13)	<0.001
Body mass index, kg/m^2 (SD)	27 (6)	27 (6)	28 (5)	<0.001
CK peak, n (%)				0.046
Tertile 1	589 (35)	280 (37)	305 (32)	
Tertile 2	544 (32)	227 (30)	315 (33)	
Tertile 3	514 (30)	216 (29)	295 (31)	
Cardiologist involved in care, n (%)				<0.001
None	140 (8)	120 (15)	19 (2)	
As main care provider	1,536 (86)	595 (74)	938 (94)	
As consultant	130 (7)	92 (11)	36 (4)	
Reperfusion, n (%)	597 (33)	138 (17)	457 (46)	<0.001
Medications at discharge				
Aspirin	1,213 (67)	469 (58)	742 (75)	<0.001
Beta-blockers	993 (55)	336 (42)	656 (66)	<0.001
ACE inhibitors	349 (19)	180 (22)	168 (17)	0.005
Statins	196 (11)	54 (7)	142 (14)	<0.001

ACE = angiotensin-converting enzyme; CK = creatine phosphokinase; MI = myocardial infarction.

primary attending physician or serving as a consultant, and measurement of the ejection fraction within 30 days after MI. This model was used to determine propensity scores that were used to analyze survival. First, survival at three years was compared between participants and nonparticipants stratified according to the estimated propensity to participate. We then examined the association between survival during the entire follow-up and participation in cardiac rehabilitation, while controlling for the propensity to participate in a Cox proportional hazards regression model. Results were reported as relative risks (RR) with 95% CI.

Population-attributable risks were calculated to estimate the proportion of deaths that could be attributed to nonparticipation in cardiac rehabilitation. A nonlinear effect of year of MI was accounted for by testing for a quadratic term in the models, and tests for interaction between participation and age and gender were conducted.

All analyses were weighted to account for the sampling strategy, where the weights applied were the inverse of the sampling fractions for each ICD-9 target code used to ascertain MI. Specifically, a weight of 1 was used for ICD-9 code 410, a weight of 2 for code 411, and weights of 10 for codes 412 to 414. Analyses were performed using the statistical software packages S-Plus, version 6.0.4 (Insightful Corp., Lucent Technologies, Seattle, Washington) and SAS, version 8.2 (SAS Institute Inc., Cary, North Carolina). Missing values did not exceed 5% for any of the variables used in the regression analysis. A p value of 0.05 was selected for the threshold of statistical significance, except when testing for interactions where p values up to 0.10 were considered significant. This study was approved by the Mayo Foundation Institutional Review Board.

RESULTS

Baseline characteristics. Between 1982 and 1998, 2,019 persons with an incident MI were hospitalized in Olmsted County. Among these, 198 died in hospital and were thus ineligible to participate in rehabilitation. These persons were excluded from analyses and, compared with study subjects, were older, more likely to be women, to have higher peak CK values, and to have greater comorbidity ($p < 0.01$ for all comparisons). Of the 1,821 remaining study subjects, 765 (42%) were women and 839 (46%) were age 70 years and older. Their baseline characteristics are presented in Table 1. Over time, the mean age of the study subjects increased, as did the proportion of women and the number of comorbid conditions ($p < 0.05$ for all time trends).

Participation in cardiac rehabilitation. Overall, 55% of persons with incident MI dismissed from the hospital participated in cardiac rehabilitation. Among women, participation was 38% compared with 67% among men (OR

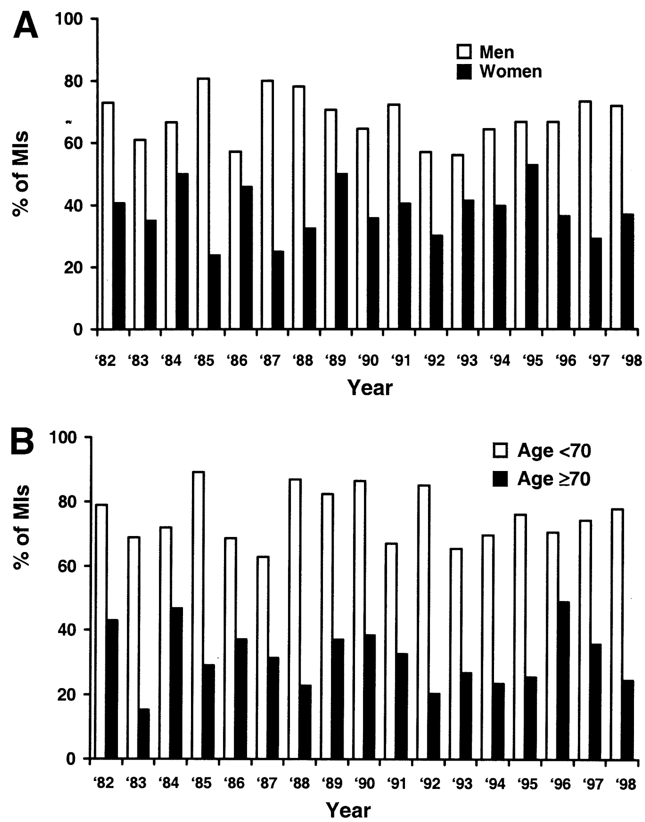

Figure 1. Time trends in participation in cardiac rehabilitation between 1982 and 1998, expressed as percentage of the total number of myocardial infarctions (MIs) occurring in each year by gender **(A)** and age **(B)**.

0.30; 95% CI 0.25 to 0.37, $p < 0.001$). Participation declined with increasing age, with 81% of persons younger than age 60 years participating, 66% of persons age 60 to 69 years, and 32% of persons age 70 years and older (age 60 to 69 years: OR 0.46, 95% CI 0.34 to 0.61; age 70 years and older: OR 0.11, 95% CI 0.09 to 0.14). Participation remained stable over time ($p = 0.22$) among both genders and age groups (Fig. 1). Participants exhibited similar trends over time in baseline characteristics as the whole study population with trends toward increasing age, proportion of women, and comorbidity.

Increased participation in rehabilitation was associated with smoking, hyperlipidemia, greater body mass index, LVEF, and a familial history of heart disease. Participation was greater if a cardiologist was involved in the care of the patient at the time of index MI, with a graded response indicated by the strongest association with participation if a cardiologist was the primary care provider compared with involved in a consultative manner or not involved (p for trend <0.001). Use of reperfusion therapy was associated with greater participation in cardiac rehabilitation.

Lesser participation was associated with older age, female gender, personal history of heart disease, hypertension, diabetes mellitus, and comorbidities. The negative association between participation in cardiac rehabilitation and comorbidity exhibited a dose-response effect, with participation decreasing further as the number of comorbidities increased. Participation was not associated with the season of the year when the index MI occurred.

Table 2. Characteristics Associated With Participation in Cardiac Rehabilitation

	OR (95% CI)	p Value
Univariate analysis		
Age		
<60 yrs	1	<0.001
60–69 yrs	0.46 (0.34–0.61)	
≥70 yrs	0.11 (0.09–0.14)	
Female gender	0.30 (0.25–0.37)	<0.001
Diabetes mellitus	0.46 (0.36–0.58)	<0.001
Hypertension	0.53 (0.44–0.64)	<0.001
Current smoker	2.22 (1.80–2.75)	<0.001
Hyperlipidemia	1.46 (1.20–1.78)	<0.001
Familial history of heart disease	2.34 (1.83–3.00)	<0.001
Personal history of heart disease	0.77 (0.63–0.94)	0.010
Charlson index		
0	1	<0.001
1 or 2	0.38 (0.31–0.47)	
3 or more	0.13 (0.09–0.17)	
BMI (kg/m^2, per unit of BMI)	1.04 (1.02–1.05)	<0.001
LVEF (%, per unit EF)	1.03 (1.02–1.04)	<0.001
Peak CK		
Tertile 1	1	0.138
Tertile 2	1.27 (1.01–1.61)	
Tertile 3	1.25 (0.99–1.59)	
Involvement of cardiologist in care		<0.001
None	1	
As consultant	2.5 (1.3–4.6)	
As primary care provider	10.0 (6.1–16.3)	
Reperfusion	3.97 (3.18–4.97)	<0.001
Multivariable analysis*		
Age		<0.001
<60 yrs	1	
60–69 yrs	0.60 (0.41–0.88)	
≥70 yrs	0.23 (0.16–0.33)	
Female sex	0.45 (0.34–0.60)	<0.001

*Adjusted for year of index MI, comorbidity, peak CK ratio, involvement of cardiologist in care, reperfusion therapy, hyperlipidemia, familial history of coronary disease, and LVEF.

BMI = body mass index; CK = creatine phosphokinase; EF = ejection fraction; LVEF = left ventricular ejection fraction; MI = myocardial infarction; OR = odds ratio.

After adjustment for coexisting conditions associated with participation in cardiac rehabilitation (including year of index MI, comorbidity, peak CK ratio, LVEF, involvement of cardiologist in care, reperfusion therapy, hyperlipidemia, and familial history of coronary disease), there were strong independent negative associations between lower participation in cardiac rehabilitation and female gender (adjusted OR 0.45, 95% CI 0.34 to 0.60) and older age (age 60 to 69 years: OR 0.60, 95% CI 0.41 to 0.88; age 70 years and older: OR 0.23, 95% CI 0.16 to 0.33) (Table 2).

Participation in cardiac rehabilitation and outcome. After 6.6 ± 4.6 years of follow-up, 774 deaths and 493 recurrent MIs occurred. The Kaplan-Meier survival curves for the cohort stratified by participation in rehabilitation are shown in Figure 2 as well as the expected survival of the Minnesota total population.

Participants exhibited a marked survival advantage as

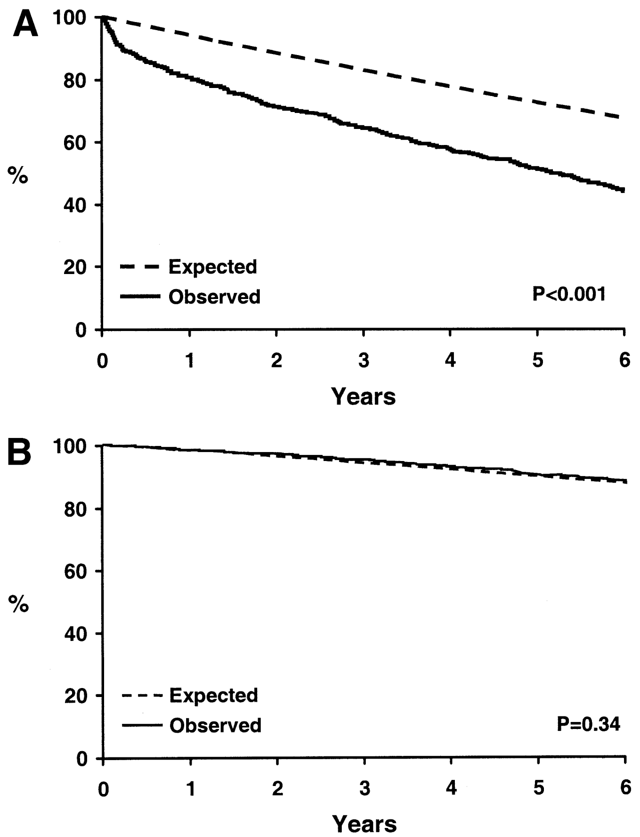

Figure 2. Expected and observed survival by participation in cardiac rehabilitation. **(A)** non-participants; **(B)** participants.

compared with non-participants, with three-year survival of 95% (95% CI 93% to 96%) compared with 64% (95% CI 61% to 68%) among non-participants (log-rank p value <0.001). The three-year survival among non-participants was significantly lower than the expected survival of the Minnesota total population at 83% ($p < 0.001$). Conversely, there was no difference between the three-year survival among participants and the 95% expected survival of the Minnesota total population ($p = 0.34$).

When patients were stratified by the propensity to participate in cardiac rehabilitation, survival remained greater among patients who participated in cardiac rehabilitation than among non-participants. Figure 3 shows the mortality three years after the index MI according to quartiles of the propensity to participate. As shown, mortality was lower among persons in the highest quartile of propensity to participate, and importantly within each quartile of propensity, mortality was consistently lower among participants than among non-participants. The benefit associated with participation was large, with values for the relative reduction in mortality of 63%, 67%, 72%, and 78% in quartile 1 (lowest propensity) to 4 (highest propensity), respectively, as compared with non-participants. No difference in the magnitude of the relative reduction in mortality was detected ($p = 0.79$).

When the attributable risk of death related to non-participation was calculated by quartiles of the propensity

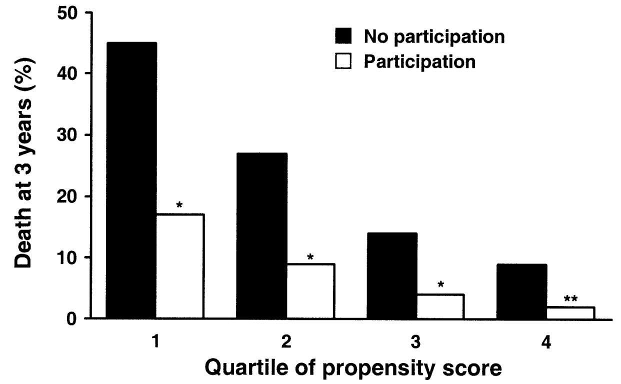

Figure 3. Mortality within three years after myocardial infarction by participation in rehabilitation stratified by quartile of propensity to participate. *$p < 0.001$ for comparison between participation and no participation; **$p < 0.005$.

to participate, the attributable risk was the largest among individuals with the lowest propensity to participate (Table 3). Indeed, in the first quartile of propensity, the attributable risk of death was 0.29 (95% CI 0.14 to 0.45), indicating that, within this quartile, up to 29% of the deaths could be attributed to non-participation.

In a proportional hazards regression model, cardiac rehabilitation after MI was univariately associated with a marked improvement in survival (RR 0.18; 95% CI 0.16 to 0.22). Adjusting for the propensity to participate attenuated this association; however, participation in cardiac rehabilitation remained associated with a 56% improvement in survival post MI (RR 0.44; 95% CI 0.36 to 0.54; $p < 0.001$), which was similar across age and gender groups.

With regard to recurrent MI, participation in cardiac rehabilitation was associated with a 28% reduction in the risk of recurrent MI after adjustment for propensity score, age, and gender (RR 0.72, CI 0.52 to 0.99, $p = 0.049$).

To assess the robustness of the protective effect of cardiac rehabilitation on survival, several ancillary analyses were conducted. First, adjustment for the use of reperfusion therapy or discharge medications (beta-blockers, angiotensin-converting enzyme inhibitors, aspirin, or statins) did not alter the protec-

Table 3. Attributable Risk of Non-Participation, in the Entire Cohort, Stratified by Age and Gender and Quartile of Propensity Score

	Attributable Risk (95% CI)
Overall	0.48 (0.43–0.53)
Men	0.55 (0.47–0.64)
Women	0.39 (0.33–0.45)
Age <70 yrs	0.27 (0.20–0.35)
Age ≥70 yrs	0.44 (0.36–0.52)
1st quartile of propensity score*	0.29 (0.14–0.45)
2nd quartile of propensity score	0.28 (0.17–0.38)
3rd quartile of propensity score	0.17 (0.07–0.28)
4th quartile of propensity score	0.17 (0.07–0.28)

*1st quartile represents those with the lowest propensity to participate, whereas those in the 4th quartile have the highest propensity to participate.
CI = confidence interval.

tive effect of rehabilitation against death or recurrent MI. A second analysis evaluated the possibility of factors not captured within the propensity score as confounders of the association between rehabilitation and survival by censoring all deaths within the first two years after the MI. This yielded a RR of 0.52 (95% CI 0.41 to 0.66; $p < 0.001$), confirming that the protective association between rehabilitation and survival persisted after excluding early deaths potentially related to comorbid conditions not captured by the Charlson index.

A third analysis examined these associations over time and demonstrated that the protective effect of rehabilitation was stronger in more recent years (p value for the participation by year interaction 0.013). The RR of death for participation versus no participation was 0.41 (95% CI 0.33 to 0.52) for 1990 as compared with 1982 and 0.28 (95% CI 0.18 to 0.43) for 1998 as compared with 1982. Over time, the study group as a whole, and participants in rehabilitation in particular, aged and comprised a growing proportion of women with increasingly greater degrees of comorbidity, thus at greater risk of death. Thus, this provided reassurance against confounding by secular trends in the baseline characteristics as an alternative explanation for the increase in the protective effect of rehabilitation in more recent years.

DISCUSSION

In this community-based cohort, approximately half of the patients participated in cardiac rehabilitation after MI, and the use of rehabilitation did not increase over time. There were disparities in participation in cardiac rehabilitation after MI, with women and elderly persons less likely to participate independently of other measurable characteristics, including cardiac risk factors, comorbidity, and MI characteristics. Participation in cardiac rehabilitation after MI was associated with large survival benefits in both genders and all age groups even after adjustment for the propensity to participate. This survival benefit appeared greater in more recent years, suggesting that the effectiveness of cardiac rehabilitation may have increased over time.

Participation in cardiac rehabilitation. National guidelines and experts recommend the use of cardiac rehabilitation after MI (4,5,21). As hospital stays decrease, cardiac rehabilitation is assuming an increasingly important role in secondary prevention. In contrast with its growing importance, there is little contemporary information on the use of cardiac rehabilitation after MI and essentially no published data on how participation may have changed over time.

Earlier studies reported that women and the elderly were less likely to participate in cardiac rehabilitation (7–10). Most published studies, however, include a preponderance of men and younger patients who experienced an MI in the early 1990s and were seldom treated with reperfusion therapy; thus, these studies may be of limited relevance to contemporary patients and treatments. A notable exception consists of a recent report from the United Kingdom that underscored the lower use of cardiac rehabilitation among women (22). However, this report did not include patients older than age 70 years, did not adjust for comorbidity, and combined angina and MI in its analysis, thus leaving the possibility of selection bias and large residual confounding as an alternate explanation for the reported association between female gender and use of rehabilitation.

The present study provides new information that helps address this gap in knowledge by reporting that over time the use of cardiac rehabilitation, although higher than national use (7) in the 1990s, remained stable over the past two decades and has been consistently lower among women and persons of more advanced age. There is evidence that women receive fewer primary prevention services before the diagnosis of CHD (23), which extends (24–29) the evidence of lesser use of cardiac procedures among women when the diagnosis of CHD is not established (24–30). In the setting of overt CHD, however, the use of cardiac services seldom differs by gender (30), and cardiac rehabilitation thus constitutes, as shown herein, a distinct exception to the published literature. With regard to age, previous reports underscored a lower use of cardiac rehabilitation in the elderly (8–10) but seldom took into account coexisting illnesses that could affect participation. The present study extends those findings by indicating that older age was associated with markedly lower participation independent of comorbidity.

These data are particularly noteworthy because women and the elderly constitute an increasingly larger proportion of persons with MI and can unequivocally experience large physiologic benefits from cardiac rehabilitation (6,8,9,12,31–40). To this end, although women and elderly patients have reduced exercise capacity at entry into rehabilitation (31,39,41–43), their relative improvements in exercise capacity are greater than those of men and younger persons (33,34).

Although this study was not designed to identify barriers to participation, insights into barriers can be inferred from this analysis. Indeed, comorbidities (6), which often limit participation, were adjusted for in the analysis using a comprehensive validated index (20). Thus, residual confounding by a major comorbid condition not included in this index is unlikely to account for the strong independent effect of age and gender on participation. Similarly, insurance coverage is unlikely to play a major role as the majority of the population of Olmsted County has health insurance (44). Additional barriers to participation not captured by the present study design may include awareness and perception, transportation, spousal care, and support networks (8,9,31,34,35,45).

Cardiac rehabilitation and outcome. Cardiac rehabilitation improves numerous intermediate end points, including exertional ischemic symptoms, depression and hostility scores, overall feelings of wellness (9,31,34,37), understanding of the disease, and compliance with risk factor modification (6,46,47).

With regard to survival, earlier randomized trials assessing the efficacy of cardiac rehabilitation after MI have been limited by small sample size. When the results of individual trials were pooled, cardiac rehabilitation was associated with survival gains of 20% to 30% (11,12,48). As these trials were conducted in the 1980s, it is uncertain that these data can be generalized to contemporary practice; furthermore, most studies included middle-aged men so that their generalizibility to contemporary patients with MI is uncertain. The present study contributes to address this gap in knowledge by indicating that substantial survival benefits are associated with participation in cardiac rehabilitation in a geographically defined, non-selected cohort of patients with MI. When the magnitude of these benefits was examined according to time, the magnitude of the survival advantage observed herein in the early 1980s was similar to that reported in randomized trials during the same period. It is noteworthy that the survival benefit associated with participation in rehabilitation is greater in more recent years, perhaps pointing to the gradually broadened scope of cardiac rehabilitation and the increasing importance of ambulatory management of CHD (6).

Two main factors could explain the survival benefit associated with cardiac rehabilitation. First, unmeasured variations in patients' severity of illness, socioeconomic status, or social support may persist despite rigorous adjustment for differences in baseline characteristics between participants and non-participants as provided by the propensity score methodology. Randomized trials would address this question more directly in a contemporary MI cohort but would be ethically problematic given the efficacy of rehabilitation, and exercise in particular, on intermediate cardiovascular end points (6).

The alternative explanation is that cardiac rehabilitation is directly causal. The causal link between cardiac rehabilitation and survival is supported by the consistency of the data pointing to a protective effect and by biologic plausibility given the efficacy of exercise-based interventions on physiologic cardiovascular end points (6). The analytical steps discussed earlier that attest to the robustness of the present data, also support causality. Although we cannot exclude that residual confounding may still partially influence the magnitude of the protective association between rehabilitation and survival, the main goal of this report is to underscore the current underuse, with marked superimposed disparities, of a process of care associated with survival benefits.

The strengths of our study include the well-defined, rigorously ascertained cohort of incident MI. Furthermore, the present data apply to a geographically defined population as opposed to most previous studies examining participation in rehabilitation, which used surveys or interviews (8–10). Thus, the results presented herein are less subject to survivor bias leading to enhanced external validity. As the quasi-totality of the population had health insurance, access to care—an important potential confounder in analyses of health care delivery—is unlikely to explain the present results (44). Rigorous propensity score methods (49) and careful adjustment approaches used to minimize selection bias in the analysis are additional strengths.

Potential limitations need to be taken into consideration while interpreting the data. Although Olmsted County is becoming more diverse (13), its racial and ethnic composition during the study period may limit the generalization of these data to groups underrepresented in the population. Odds ratios are used to report the association between age and gender and the use of cardiac rehabilitation. Whereas these approximate the RR if the exposure is infrequent, such is not the case in this cohort for participation in rehabilitation, thus the ORs presented herein should not be interpreted as equivalent to RRs (50).

Despite rigorous analyses, the protective effect of rehabilitation on survival may still be in part confounded by indication as in any observational study. However, although randomized clinical trial designs are optimal to assess the efficacy of interventions, these are not always feasible, particularly for care processes that are perceived as being established such as cardiac rehabilitation. Furthermore, studies of geographically defined populations such as the present one complement clinical trials by including the entire spectrum of medical practice as opposed to more selected trial participants (51). The propensity score method used herein offers methodological advantages over traditional multivariable adjustment (49) to minimize the effect of residual confounding.

Although hyperlipidemia was positively associated with participation in rehabilitation, it must be kept in mind that hyperlipidemia was clinically defined in this cohort, thus the study potentially underestimates the true prevalence of hyperlipidemia. Further studies will be needed to address adherence rates to cardiac rehabilitation programs.

Although the use of aspirin and beta-blockers is seemingly low in this cohort, several points should be mentioned. First, the percent use reported herein includes a broad time range (1982 to 1998). Our group has published elsewhere the trends in medication use after MI (52), showing that use of aspirin and beta-blockers has increased markedly in the past several years and currently approximates 88% and 73% for aspirin and beta-blockers, respectively.

CONCLUSIONS

In this community-based cohort, approximately half of the patients participated in cardiac rehabilitation after MI, and the use of rehabilitation did not increase over time. There were disparities in participation, with women and elderly persons less likely to participate independent of other measurable characteristics. Participation in rehabilitation was independently associated with decreased mortality and lower risk of recurrent MI after MI in both genders and all age groups, and its protective effect was stronger in more recent years. This suggests that increased participation in cardiac rehabilitation could lead to improved survival among a large proportion of patients with MI.

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